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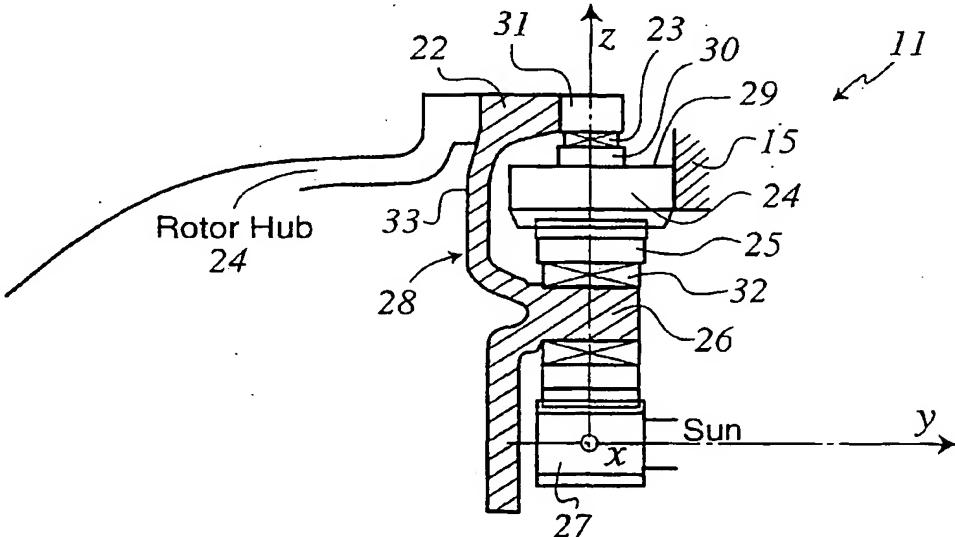
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[Continued on next page]

(54) Title: DRIVE ASSEMBLY FOR WIND TURBINES



(57) Abstract: A drive assembly for a wind turbine comprises a rotor hub (14), supporting structure such as a turbine nacelle (15), a planetary type gear transmission unit (11) comprising sun (27), planet (25) and ring (24) gears and a planet carrier (28), said ring gear being non-rotatably secured to said supporting structure (15), a main bearing (23) which rotatably supports the rotor hub (14) and planet carrier (28) relative to said ring gear and supporting structure, and said drive assembly comprising two substantially independent force transmission paths for transmission of forces reacting with forces exerted by the wind turbine rotor hub, a first of said force transmission paths acting from the rotor hub (14) via said main bearing (23) to the supporting structure (15) primarily for transmission of overhang load forces and bending moment forces and a second of said force transmission paths acting from the rotor hub (14) via said planet carrier (28) primarily for transmission of rotational forces.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## DRIVE ASSEMBLY FOR WIND TURBINES

This invention relates to a drive assembly and to a gear transmission unit for a wind turbine.

There is a continuing demand for larger wind turbines especially for offshore sites due to scarcity of suitable sites and cost of civil works. At the same time the requirements for reduction of size and weight of the machines and their components become more and more important. Typically a wind turbine rotor drives the low speed shaft of a gear transmission unit, which transforms torque and speed of the rotor to the required torque and speed of an electrical generator.

Integration of the components in a wind turbine is a way to reduce the weight and to make the drive assembly more compact, but it is important that the design and execution of the drive assembly avoids mutual interference of the external and internal loads on the different components. It is also important that the construction of an integrated drive assembly allows effective lubrication to be achieved economically and reliably.

The present invention seeks to provide an improved drive assembly and an improved gear transmission unit for a wind turbine and which permits an advantageous integration of components.

In accordance with one aspect of the present invention a drive assembly for a wind turbine comprises a rotor hub, supporting structure such as a turbine nacelle, a planetary type gear transmission unit comprising sun, planet and ring gears and a planet carrier, said ring gear being non-rotatably secured to said supporting structure, a main bearing which rotatably supports the rotor hub and planet carrier relative to said ring gear and supporting structure, and said drive assembly comprising two substantially independent force transmission paths for transmission of forces reacting with forces exerted by the wind turbine rotor hub,

a first of said force transmission paths acting from the rotor hub via said main bearing to the supporting structure primarily for transmission of overhang load forces and bending moment forces and a second of said force transmission paths acting from the rotor hub via said planet carrier primarily for transmission of rotational forces.

In accordance with another aspect of the present invention a gear transmission unit for use in a wind turbine to transmit forces from a rotor hub to a generator comprises a planetary type gear transmission unit comprising sun, planet and ring gears and a planet carrier, said ring gear being adapted for non-rotatably securing to supporting structure such as a turbine nacelle, a main bearing which rotatably supports the planet carrier and is adapted for rotatably supporting a rotor hub relative to said ring gear and supporting structure, and said gear transmission unit comprising two substantially independent force transmission paths for transmission of forces reacting in use with forces exerted by the wind turbine rotor hub, a first of said force transmission paths acting via said main bearing to the supporting structure primarily for transmission of overhang load forces and bending moment forces and a second of said force transmission paths acting via said planet carrier primarily for transmission of rotational forces.

Accordingly, the invention teaches that the overhung load forces and bending moments from the rotor are taken by a bearing which is directly connected to stationary parts instead of to the torque transmitting low speed part of the gear unit.

Preferably, as considered in an axial direction parallel with the axis of rotation of the planet carrier, said main bearing lies at a position substantially aligned axially with the axial position of at least the ring gear of the gear transmission unit.

Preferably the sun, planet and ring gears lie in a transverse plane (perpendicular to the rotation axis of said rotational forces) which also contains said main bearing.

Other preferred features are that the main bearing comprises an inner ring bearing surface of a diameter greater than that of the toothed surface of the ring gear, and that at all radial positions inwards of the toothed surface of the ring gear the second force transmission path is substantially independent of the first force transmission path.

It is further preferred that the second of said force transmission paths comprises a radially extending torque transmission member which is torsionally stiff but relatively compliant in an axial direction parallel with the axis about which the rotational forces act whereby movement of the hub in consequence of bending forces is accommodated at least in part by deflection of the torque transmission member. The torque transmission member thereby isolates the gear transmission unit from the potentially damaging effects of bending deflections experienced by the rotor hub relative to the main rotational axis of the gear transmission unit.

The present invention accordingly provides, in a further of its aspects, a drive assembly in which the main rotor bearing and gear transmission unit for a wind turbine are of an integrated construction. The wind turbine rotor hub preferably is connected to the outer ring of the main bearing. The bearing inner ring preferably is supported by, and may be directly mounted on, the ring gear of the planetary gear stage, or on a flange which connects the ring gear to the supporting structure. In an alternative construction the ring gear may provide a bearing surface for rotatable bearing components of the main bearing.

The ring gear may provide axial and radial locations for the main bearing. The ring gear may have a radially outer surface of a stepped profile to define a

shoulder for axial location of an inner bearing ring of the main bearing. The inner bearing ring may be secured axially between said shoulder and said supporting structure.

The ring gear may be provided with a reinforcing ring, and said reinforcing ring may extend axially and or radially beyond the toothed surface of the ring gear. Said reinforcing ring may provide an axial location of the main bearing.

The main bearing may comprise a double taper bearing, and said double taper bearing may comprise a single outer bearing ring. The rotor hub may be rigidly secured relative to said single outer bearing ring. The double taper bearing may comprise rollers arranged in an O configuration in which the rollers of one series increase in diameter in a direction away from the rollers of the other series of the pair.

In a yet further of its aspects the present invention provides a wind turbine comprising rotors, a generator and a drive assembly of a type in accordance with the present invention.

The gear transmission unit, e.g. a housing thereof, may be arranged to support an electrical generator.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings in which: -

Figure 1 is an elevation view of a wind turbine having a drive assembly of the present invention;

Figure 2 is a sectional view of part of a gear transmission unit in accordance with the present invention;

Figure 3 shows part of Figure 2 in more detail;

Figures 4, 5 and 6 each show variations of the construction of Figures 2 and 3;

Figures 7 shows part of Figure 6 in more detail, and

Figures 8 and 9 each show further variations of the construction of Figures 2 and 3.

A wind turbine 10 (see Figure 1) comprises a gear transmission unit 11 which acts to transmit torque from rotor blades 12 and rotor hub 14 to an electrical generator 13, the gear transmission unit comprising an epicyclic gear unit. The gear transmission unit and generator are housed in and supported by a nacelle 15.

The gear transmission unit 11 is now described in more detail with reference to Figures 2 and 3. The gear transmission unit 11 comprises an epicyclic gear unit having four planet gears 25, a sun gear 27 a planet carrier 28, and a ring gear 24 which is non-rotatably mounted relative to the nacelle structure 15.

The sun gear is connected to an output shaft (not shown) which connects either to a further gear unit or direct to the rotor of the generator 13.

The radially outer surface 29 of the ring gear 24 provides location and support for the inner ring 30 of a main bearing 23.

The outer ring 31 of the main bearing has secured thereto the rotor hub 14 and, interposed between the rotor hub and ring 31, the outer region 22 of the planet carrier 28.

The planet carrier 28 comprises four bearing support studs 26 uniformly circumferentially spaced to locate bearings 32 which rotatably support the four planet gears 25. The planet carrier 28 has an annular region 33 which extends radially between the radial position of the bearing studs 26 and the outer region 22 and is designed to be relatively stiff, in a circumferential direction about the Y axis, for transmission of torque between the region 22 and the bearing studs 26, but to be relatively flexible about the X and Z axis.

In the aforescribed construction the torque acting on the rotor hub 14 under action of the rotor blades 12 is transmitted to the planet gears 25 via the

planet carrier 28 rotatably mounted at its outer region 22 to the outer ring 31 of bearing 23. Bending moments and axial forces in the Y direction exerted by the rotor hub in this construction are transmitted direct to the bearing 23. The flexibility of the annular portion 33 of the planet carrier 28 assists to substantially isolate those forces from the planet gears.

Figure 4 shows a variation 40 in which the planet carrier 41 is provided with three integral and uniformly circumferentially spaced studs 42 which support a planet bogie plate 43. The planet bogie plate 43 provides support for three circumferentially uniformly spaced shafts 44 arranged each to self adjust in angular position on the plate 43. Each shaft 44 provides support, at opposite sides of the plate 43, for a pair of bearings 45, 46 about which each of a pair of planet gears 47, 48 are rotatably mounted for engagement with the ring gear 49.

In a further variation 50, shown in Figure 5, the planet carrier 56 is of a cage type design. In this construction each of three planet bearing support shafts 51 is supported at one axial end 52 by the part 53 of the planet carrier that extends radially outwards to be supported by the outer ring of the main bearing 54 whilst the other end 55 is supported by an auxiliary driving plate 57 carried by three circumferentially uniformly spaced supports 58 provided at positions interposed circumferentially between the shafts 51. The plate 57 is provided with a central aperture 59 to which an output shaft 60 extends from the sun gear 61.

Figure 6 shows a further variation of the construction of Figures 2 and 3. In this construction the planet carrier is constructed substantially similar to that described with reference to Figure 5. However the ring gear 63 differs in so far as part of the outer periphery of the gear is surrounded by a reinforcing support ring 64. The reinforcing ring is either formed integrally, e.g. forge rolled, with the outer ring 63 or permanently secured thereto, for example by being a shrink fit thereon. The presence of the support ring, provided axially at a position spaced from the

nacelle structure 15 provides an abutment surface 65 for axial location of the inner ring of the main bearing 66. The main bearing 66 may be a double taper type bearing, shown in more detail in Figure 7. The main bearing comprises an inner ring of a split construction comprising two taper rings 67. The bearing additionally comprises a single outer ring 68 of double taper form.

A further variation of the construction of Figures 2 and 3 is shown in Figure 8. In this construction 80 the inner ring of the main rotor bearing 81 contrasts with aforescribed constructions in so far as it is not directly mounted on or supported by the ring gear 82. Instead, the inner ring of the bearing 81 is supported by a flange assembly 83 secured to the nacelle structure 15. In the construction 90 of Figure 9 the bearing inner ring is connected substantially directly to the nacelle structure 15 at position 91.

Whilst the constructions of Figures 8 and 9 show that the inner ring of the main bearing is non-rotatably secured relative to the nacelle structure 15, it is to be understood that the outer ring of the main bearing may be secured to the nacelle structure and that the rotor hub and planet carrier may be rotatably supported by the inner ring of the bearing.

In the aforescribed constructions the sun, planet and ring gears are all substantially aligned with one another as considered in an axial direction parallel with the axis of rotation of the planet carrier. A further feature common to the described embodiments of the invention is that the main bearing comprises an inner ring bearing surface the diameter of which is greater than that of the toothed surface of the ring gear. The substantially direct attachment of the rotor hub to the main bearing results in provision of a torque transmission path which at all radial positions inwards of the toothed surface of the ring gear is substantially independent of the force transmission path by which bending and other forces

other than those causing rotation about the rotational axis Y, are transmitted to the nacelle support structure.

A benefit arising from the drive assembly, and the gear transmission unit of the present invention as used in a wind turbine is that the overhung loads generated by the wind turbine rotor blades have only a minimal effect on the planet driving components and on the gear meshing contact of the planetary gear stage. This allows for an increased power rating of the gear transmission unit or a reduction of dimension for a given power rating as compared with hitherto known constructions. It is also to be appreciated that the forces generated in gear meshing of the planets have only a minimal effect on the load distribution over the bearing rollers in the main bearing, thus increasing the load capacity of the main bearing or allowing for reduction of dimensions of that bearing for a given load capability.

## CLAIMS

1. A drive assembly for a wind turbine comprising a rotor hub, supporting structure such as a turbine nacelle, a planetary type gear transmission unit comprising sun, planet and ring gears and a planet carrier, said ring gear being non-rotatably secured to said supporting structure, a main bearing which rotatably supports the rotor hub and planet carrier relative to said ring gear and supporting structure, and said drive assembly comprising two substantially independent force transmission paths for transmission of forces reacting with forces exerted by the wind turbine rotor hub, a first of said force transmission paths acting from the rotor hub via said main bearing to the supporting structure primarily for transmission of overhang load forces and bending moment forces and a second of said force transmission paths acting from the rotor hub via said planet carrier primarily for transmission of rotational forces.
2. A drive assembly according to claim 1, wherein, as considered in an axial direction parallel with the axis of rotation of the planet carrier, the ring gear is substantially aligned axially with the main bearing.
3. A drive assembly according to claim 1 or claim 2, wherein the main bearing comprises an inner ring bearing surface of a diameter greater than that of the toothed surface of the ring gear.
4. A drive assembly according to any one of the preceding claims, wherein the sun, planet and ring gears lie in a transverse plane which contains said main bearing.

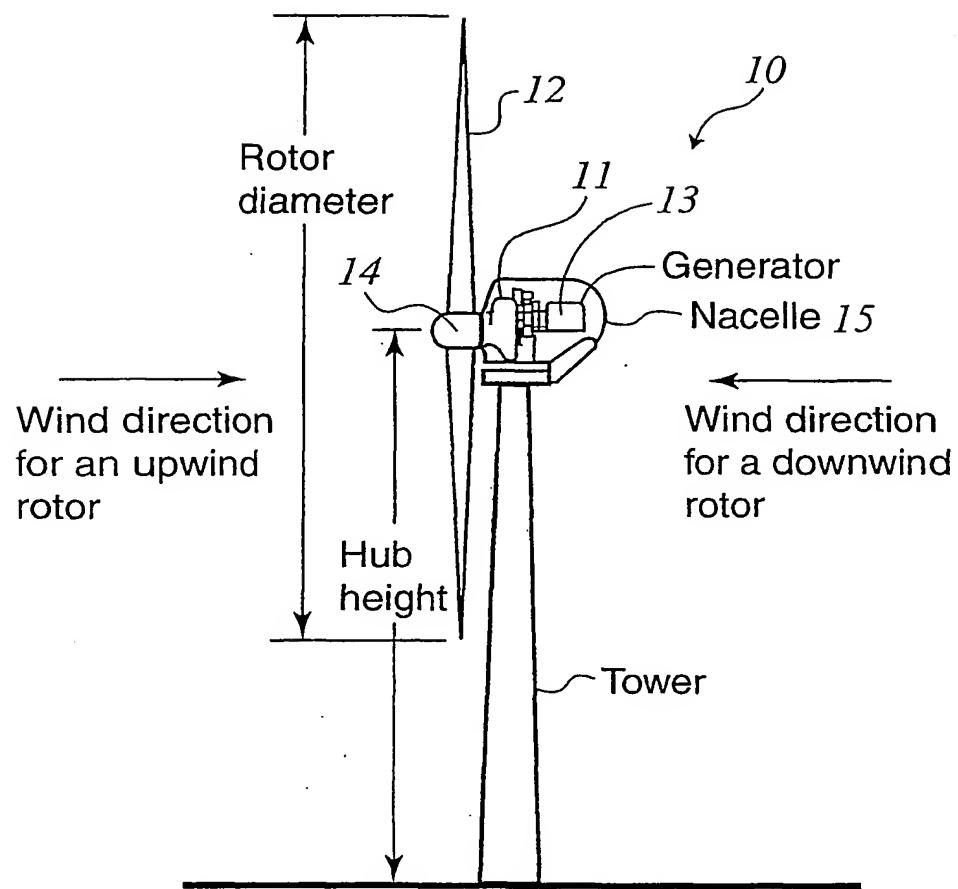
5. A drive assembly according to any of the preceding claims, wherein at all radial positions inwards of the toothed surface of the ring gear the second force transmission path is substantially independent of the first force transmission path.
6. A drive assembly according to any of the preceding claims, wherein the second of said force transmission paths comprises a radially extending torque transmission member which is torsionally stiff but relatively compliant in an axial direction parallel with the axis about which the rotational forces act.
7. A drive assembly according to any one of the preceding claims, wherein the outer ring of the main bearing is connected or adapted for connection to a wind turbine rotor hub.
8. A drive assembly according to any one of the preceding claims, wherein the main bearing and gear transmission unit are of an integrated construction.
9. A drive assembly according to claim 8 wherein the ring gear provides a bearing surface for rotatable bearing components of the main bearing.
10. A drive assembly according to any one of claims 1 to 8, wherein an inner ring of the main bearing is supported by the ring gear.
11. A drive assembly according to claim 10, wherein the ring gear provides axial and radial locations for the main bearing.

12. A drive assembly according to claim 11, wherein the ring gear has a radially outer surface of a stepped profile to define a shoulder for axial location of an inner bearing ring of the main bearing.
13. A drive assembly according to claim 11, wherein the inner bearing ring is secured axially between said shoulder and said supporting structure.
14. A drive assembly according to any one of the preceding claims, wherein the ring gear is provided with a reinforcing ring.
15. A drive assembly according to claim 14, wherein said reinforcing ring extends axially and or radially beyond the toothed surface of the ring gear.
16. A drive assembly according to claim 14 or claim 15 when dependant on claim 12 or claim 13, wherein the reinforcing ring provides an axial location of the main bearing.
17. A drive assembly according to any one of claims 1 to 9, wherein the main bearing is mounted on a flange which connects the ring gear to the supporting structure.
18. A drive assembly according to any one of the preceding claims, wherein the main bearing comprises a double taper bearing.
19. A drive assembly according to claim 18, wherein the double taper bearing comprises a single outer bearing ring.

20. A drive assembly according to claim 19, wherein the rotor hub is rigidly secured relative to said single outer bearing ring.
21. A drive assembly according to any one of claims 18 to 20, wherein the double taper bearing comprises rollers arranged in an O configuration in which the rollers of one series increase in diameter in a direction away from the rollers of the other series of the pair.
22. A drive assembly according to any one of the preceding claims, wherein the gear transmission unit is adapted to support an electrical generator.
23. A drive assembly for a wind turbine according to claim 1, and substantially as hereinbefore described.
24. A wind turbine comprising rotors, an electrical generator and a drive assembly according to any one of the preceding claims.
25. A gear transmission unit for use in a wind turbine to transmit forces from a rotor hub to a generator, said gear transmission unit comprising a planetary type gear transmission unit comprising sun, planet and ring gears and a planet carrier, said ring gear being adapted for non-rotatably securing to supporting structure such as a turbine nacelle, a main bearing which rotatably supports the planet carrier and is adapted for rotatably supporting a rotor hub relative to said ring gear and supporting structure, and said gear transmission unit comprising two substantially independent force transmission paths for transmission of forces reacting in use with forces exerted by the wind turbine rotor hub, a first of said force transmission paths acting via said main bearing to the supporting structure

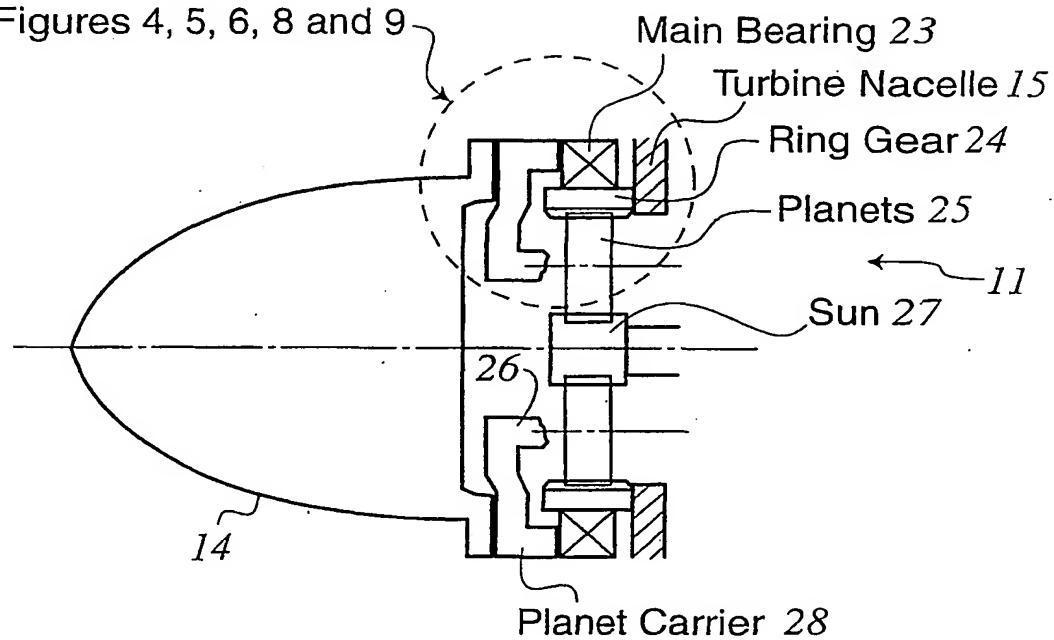
primarily for transmission of overhang load forces and bending moment forces and a second of said force transmission paths acting via said planet carrier primarily for transmission of rotational forces.

26. A gear transmission unit according to claim 25, and substantially as hereinbefore described.

**FIG. 1**

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Alternative details in  
Figures 4, 5, 6, 8 and 9



**FIG. 2**

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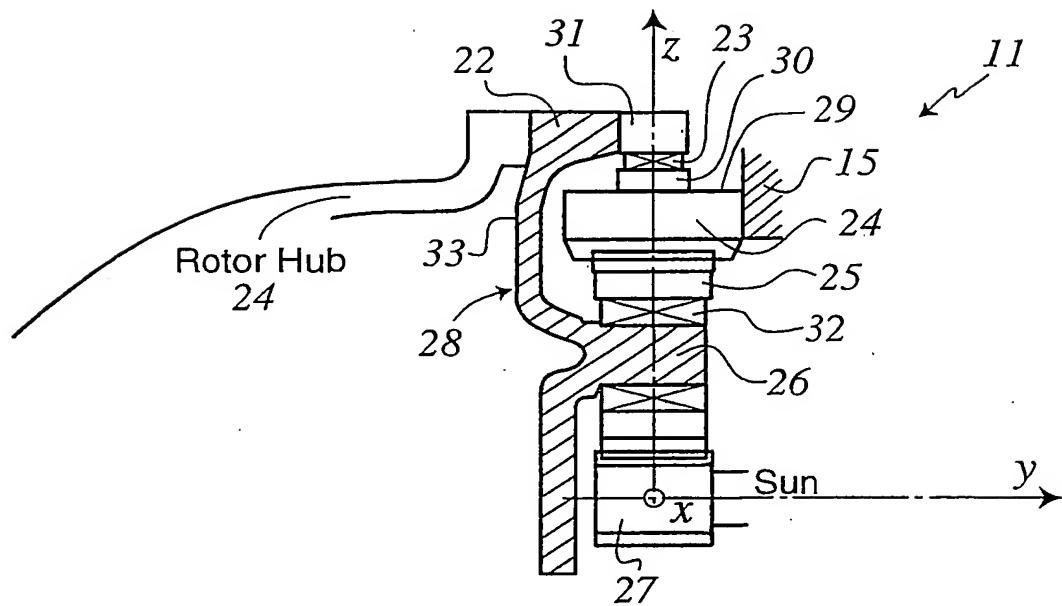
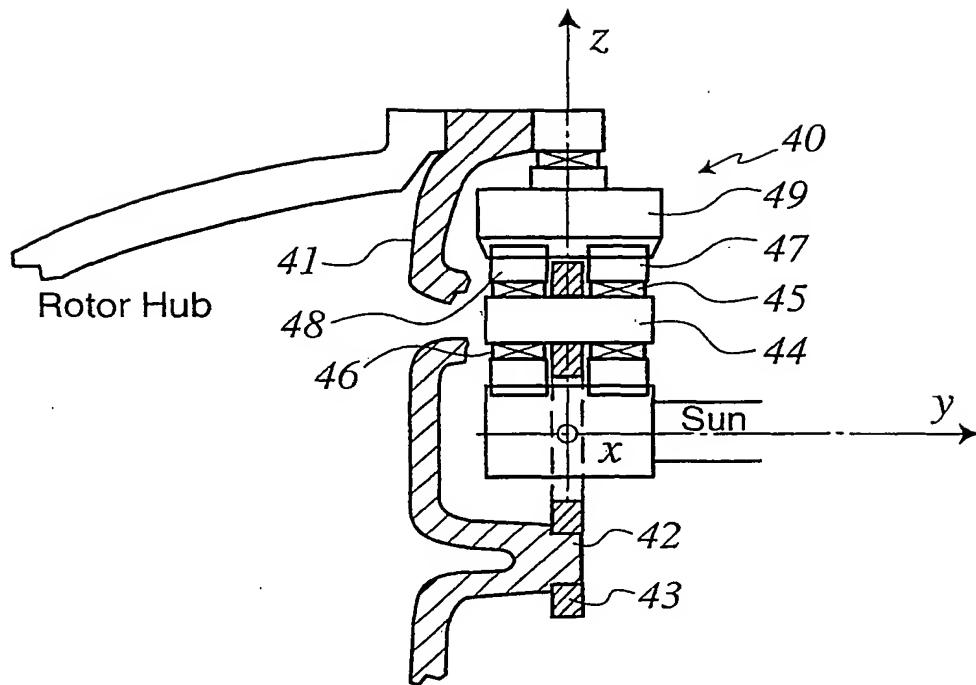
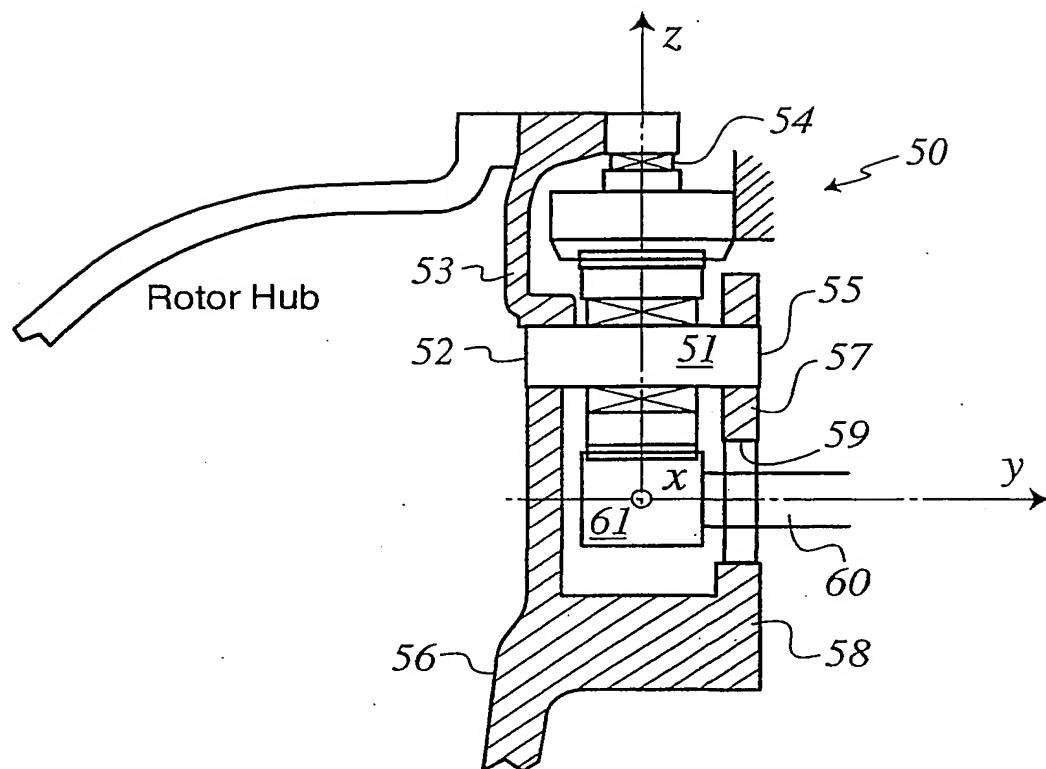


FIG. 3

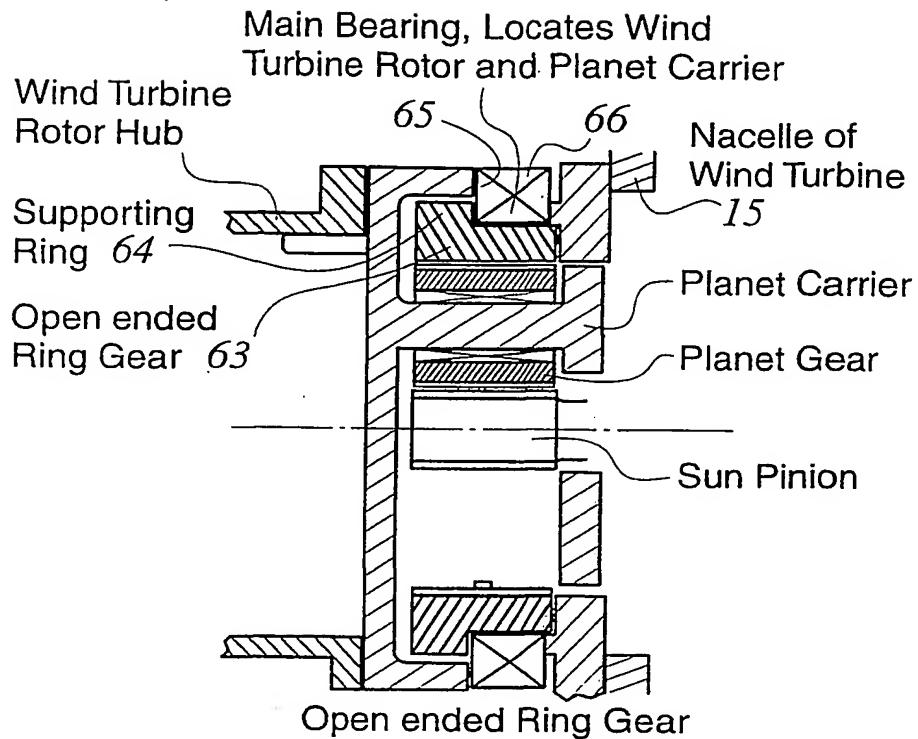
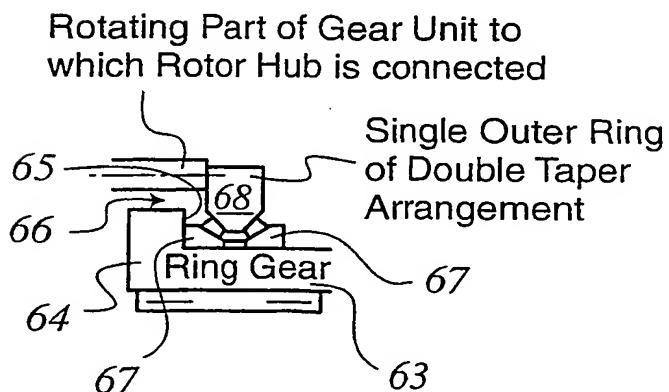


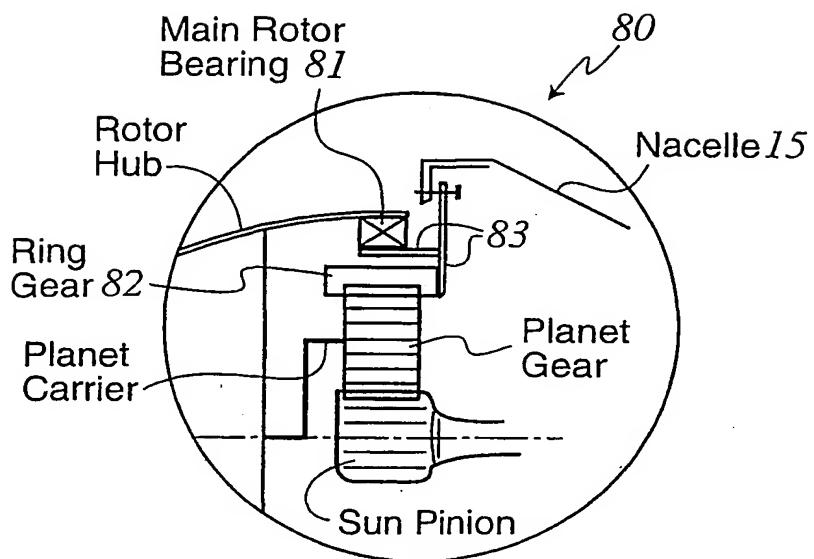
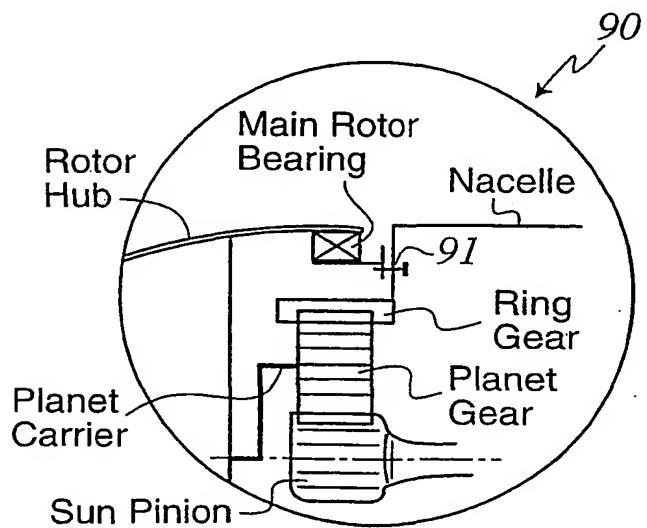
**FIG. 4**

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**FIG. 5**

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**FIG. 6****FIG. 7**

**FIG. 8****FIG. 9**

## INTERNATIONAL SEARCH REPORT

Int'l. Appl. No.  
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A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 F03D11/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F03D F16H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 11338 A (HEHENBERGER GERALD) 18 April 1996 (1996-04-18) the whole document figures -----	1-3,6-26
X	US 3 792 629 A (APPLEBURY W) 19 February 1974 (1974-02-19) figure 2 -----	1-3,6-26

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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Inte over Application No

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